## 0.a. Goal

Goal 6: Ensure availability and sustainable management of water and sanitation for all

## 0.b. Target

Target 6.6: By 2020 protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

## 0.c. Indicator

Indicator 6.6.1: Change in the extent of water-related ecosystems over time

## 0.e. Metadata update

Last updated: 09 May 2018

## 0.f. Related indicators

# Related indicators

6.3.2, 6.4.1, 6.4.2, 6.5.1, 6.5.2, 15.3.1

## 0.g. International organisations(s) responsible for global monitoring

# Institutional information

## Organization(s):

UN Environment (United Nations Environment Programme)

## 2.a. Definition and concepts

# Concepts and definitions

## Definition:

The indicator includes five categories: 1) vegetated wetlands, 2) rivers and estuaries, 3) lakes, 4) aquifers, and 5) artificial waterbodies. For purposes of this methodology, the text refers only to these five ecosystem category terminologies. To address its complexity, Indicator 6.6.1 has been divided into 5 Sub-Indicators to capture the various data sources and methodologies required for monitoring components of the Indicator. Data sources come from a combination of ground sampling and earth observations. Depending on the type of ecosystem and the type of extent being measured, the data collection methodology can also differ greatly. A progressive monitoring approach with two levels is proposed:

Level 1: 2 Sub-Indicators based on globally available data from earth observations which will be validated by countries against their own methodologies and datasets:

- Sub-Indicator 1 – spatial extent of water-related ecosystems
- Sub-Indicator 2 – water quality of lakes and artificial water bodies
- Level 2: Data collected by countries through 3 Sub-Indicators:
- Sub-Indicator 3 – quantity of water (discharge) in rivers and estuaries
- Sub-Indicator 4 – water quality imported from SDG Indicator 6.3.2
- Sub-Indicator 5 – quantity of groundwater within aquifers

A full methodology for this indicator is available in the document entitled, “Monitoring Methodology for SDG Indicator 6.6.1”.

# Concepts:

The concepts and definitions used in the methodology have been based on existing international frameworks and glossaries unless where indicated otherwise below.

***Water-related ecosystems*** – includes five categories: 1) vegetated wetlands, 2) rivers and estuaries, 3) lakes, 4) aquifers, and 5) artificial waterbodies. For purposes of this methodology, the text refers only to these five ecosystem category terminologies. The majority of water-related ecosystem types monitored in Indicator 6.6.1 contain freshwater, with the exception of mangroves and estuaries which contain brackish waters and are included in Indicator 6.6.1. Ecosystems containing or within salt waters are not included as these are covered within other SDG indicators (Goal 14). Other categories of wetlands aligning with the Ramsar Convention definitions are captured within the ecosystem category of ‘vegetated wetlands’.

Vegetated Wetlands – the water-related ecosystem category of vegetated wetlands includes swamps, fens, peatlands, marshes, paddies, and mangroves. This definition is closely related to the Ramsar Convention on Wetlands definition of wetlands, which is: “areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres” with the exception that salt waters are not included in Indicator 6.6.1 reporting (as they are covered in SDG 14) and with the exception that vegetated wetlands are distinct from the other ecosystem categories of lakes, rivers and estuaries, aquifers, and artificial waterbodies. Vegetated wetlands have been separated as their own ecosystem category because of their importance for target achievement and because the methodology for monitoring them with earth observations is unique from other open waters. The data generated by applying this methodology will also generate data required by countries to report to the Ramsar Convention on Wetlands.

***Artificial Waterbodies*** – the water-related ecosystem category of artificial waterbodies includes open waterbodies created by humans such as reservoirs, canals, harbors, mines and quarries. While it is recognized that these are not traditional water ecosystems which should be protected and restored, in some countries they hold a noteworthy amount of freshwater and have thus been included.

***Open Water*** – as any area of surface water unobstructed by aquatic vegetation. This includes the following 3 water-related ecosystem categories: rivers and estuaries, lakes, and artificial waterbodies.

***Extent*** – has been expanded beyond spatial extent to capture additional basic parameters needed for the protection and restoration of water-related ecosystems. Extent includes three components: the spatial extent or surface area, the quality, and the quantity of water-related ecosystems.

***Change*** – a shift from one condition of extent to another over time within a water-related ecosystem, measured against a point of reference.

## 3.a. Data sources

# Data sources

**Description:**

***Sub-Indicator 1:*** Open water spatial extent data, acquired by the Landsat 5, 7 and 8 satellites at a 30 m resolution, has been generated for the entire globe from 2001-2015. From 2016 onwards (up to and including 2030), higher spatial and temporal resolution satellites, including both optical and radar satellites, will be used. For example, 20 m Sentinel 1 (radar) and 10 m Sentinel 2 (optical) satellites, used in combination with Landsat satellites, will allow for a more precise delineation of water bodies both in spatial terms (due to the higher spatial resolution) and in temporal terms (due to the higher revisit time). Additional datasets will be used refine open water spatial extent data, including the Global Reservoir and Dam (GRanD) geospatial database. To generate spatial extent of vegetated wetlands, a combination of imagery from Landsat 8 and Sentinel 1 and 2 will be used. This will be augmented by other existing global datasets such as the Global Mangrove Watch (GMW) annual mangrove maps, as well as the most locally-adapted geospatial datasets capturing topography, hydrography, drainage networks, and soil types.

***Sub-Indicator 2***: Chl and TSS lake observations are obtained from combined Landsat and Sentinel satellites paired with instruments like OLCI, MODIS, and VIIRS. The sensor instruments used to detect TSS and Chl determine the spatial resolution of water quality within lakes which can be detected. Some of the more accurate water quality sensors have 250-350 meter resolution, while less accurate sensors can detect TSS and Chl changes to 100 m resolution.

***Sub-Indicator 3***: The source of data for monitoring discharge for this Sub-Indicator is primarily from ground in situ measurements within rivers and estuaries, though modelled data is also acceptable.

***Sub-Indicator 4***: The source of data for monitoring water quality for this Sub-Indicator is from ground in situ measurements within water-related ecosystems.

***Sub-Indicator 5***: The source of data for monitoring groundwater quantity for this Sub-Indicator is from ground in situ measurements of groundwater level within aquifers, though modelled data is also acceptable.

## 3.b. Data collection method

## Collection process:

Sub-Indicators 1 and 2: All globally available data generated for Sub-Indicators 1 and 2 is shared with countries for validation. This geospatial data will be generated annually at national, sub-national, and waterbody scales. While this data is generated annually, the measurement to report change in extent

requires validation every five years. Validated annual datasets will be utilized by the custodian agencies to generate percentage changes on behalf of countries.

Sub-Indicators 3, 4, and 5: All data collected within countries for Sub-Indicators 3, 4, and 5 will be submitted to the custodian agencies for review and quality assurance checks against the methodology minimum criteria. This review process will be facilitated via email communication through the global help desk. Once annual ‘raw’ data is reviewed, percentage change calculations will be completed and validated between the custodian agencies and the national representative.

## 3.c. Data collection calendar

# Calendar

## Data collection:

Annual estimation of sub-indicators 1 and 2 released around May. Every five years data will be collected through a national data drive as follows: 2017, 2022, 2027.

## 3.d. Data release calendar

## Data release:

First reporting cycle: June 2018; Second reporting cycle: June 2023; Third reporting cycle: June 2028.

## 3.e. Data providers

# Data providers

1. GEMS/Water National Focal Points, in consultation with NSOs
2. Satellite data from ESA and NASA

## 3.f. Data compilers

# Data compilers

1. UN Environment (United Nations Environment Programme)

## 4.a. Rationale

## Rationale:

Target 6.6 aims to “protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes” through Indicator 6.6.1 which aims to understand how and why these ecosystems are changing in extent over time. All of the different components of Indicator 6.6.1 are important to form a comprehensive picture that enables informed decisions towards the protection and restoration of water-related ecosystems. However, a lack of data within countries to support Indicator 6.6.1 has become clear through the 2017 pilot testing and thus a combination of national data and data based on satellite images is proposed. All data generated is processed using internationally recognized methodologies, resulting in high quality global datasets with extensive spatial and temporal scale.

## 4.b. Comment and limitations

## Comments and limitations:

This methodology mobilizes the collection of widely available earth observation data on spatial extent and some water quality parameters which will be validated by countries. The data itself in the form of images and numbers is straightforward to understand. However, the methodologies used to generate this data are technical in nature and some countries may wish understand these better. The methodology employs internationally recognized methods, from expert communities such as the Group on Earth Observation (GEO) and international space agencies, to derive statistically sound and the most technologically advanced earth observation datasets for Sub-Indicators 1 and 2. These organizations will also be engaged to provided tools and training to support countries. Sub-Indicator 2 only measures two water quality parameters, while it is recognized that to determine good water quality requires measuring multiple parameters. However, globally available data can indicate potential hot spots of pollution or human disturbance allowing countries to undertake more local assessments of water quality.

The Indicator is designed in a way to generate data to allow informed decision making towards protecting and restoring water-related ecosystems. It does not measure how many water-related ecosystems have been protected and restored. It is assumed that countries would use the data to actively make decisions, but these actions are not currently being measured. The data generated should be considered alongside other data such as land use change to enable decision-makers to protect and restore water-related ecosystems.

## 4.c. Method of computation

# Methodology

## Computation method:

The 5 Sub-Indicators are computed separately and thus Indicator 6.6.1 is comprised of 5 stand-alone methodologies.

***Sub-Indicator 1: Spatial Extent of Water-related Ecosystems***

The methodology for this Sub-Indicator describes how Earth observations are generated and processed into a global spatial extent of water-related ecosystems dataset. The basic premise of this approach is that different land covers, such as snow, bare rock, vegetation, and water, reflect different wavelengths of light. Satellites continually circulate our earth, capturing images and wavelengths

reflected from every location on the globe. For any one location on earth, thousands of images can be combined to classify the site's land cover. Advanced computing technology can be programmed to digest all of these images and split the earth into land cover type pixels, one of which is open water. Open water is defined as any area of surface water unobstructed by aquatic vegetation. Thus, changes in the spatial extent of open water locations over a long period of time can be discerned including new and lost waterbodies or seasonal changes.

To distinguish one water-related ecosystem type from another, further processing of this open water data is required in conjunction with other datasets. The data generated on open water is further distinguished into lakes, rivers and estuaries versus artificial waterbodies. In addition, vegetated wetlands are discerned through further processing. The method to detect vegetated wetlands from Earth observations is based on an approach which detects the physical properties of wetland areas (e.g. soil moisture and vegetation water content) from multi-temporal SAR (Synthetic Aperture Radar) and optical satellite imagery, combined with other geospatial datasets related to the topography of the area, the hydrography of the watershed and its drainage network, and the soil types. The resulting datasets obtained from earth observations on the spatial extent of vegetated wetlands and artificial waterbodies are excluded from the calculation of spatial extent values for lakes, rivers and estuaries, to prevent duplication of spatial extent estimations.

Thus, three global datasets are generated through this methodology annually: spatial extent of lakes, rivers, and estuaries; spatial extent of artificial waterbodies; and spatial extent of vegetated wetlands. These national spatial extent datasets are provided to countries to validate. Once validated, the annual datasets are used to calculate percentage change of spatial extent over time, using a 2001-2005 baseline period. Subsequent five year averages are compared to this baseline.

$$\text{Percentage Change in Spatial Extent} = \frac{(\beta - \gamma)}{\beta} \times 100$$

Where $\beta$ = the average national spatial extent from 2001-2005

Where $\gamma$ = the average national spatial extent of any other 5 year period

***Sub-Indicator 2: Water Quality of Lakes and artificial water bodies***

The methodology for this Sub-Indicator describes how Earth observations are generated and processed into two datasets of chlorophyll a (Chl) and total suspended solids (TSS) within lakes globally. Earth observations can only provide information on concentrations of in-water materials that affect the colour of water. These materials include Chl, which is the primary pigment in phytoplankton (the primary source of food on the food-chain), and TSS. The concentrations of Chl and TSS can be used as proxies to infer other important waterbody characteristics.

Chl and TSS results are derived using empirical algorithms, generated for each individual pixel to ensure the spatial variability within each lake is fully captured. Results are averaged over a year for each lake to produce lake-wide Chl and TSS concentrations and small localized fluctuations in concentration of these two parameters are not shown. On any one day, the pixels representing each concentration of Chl or TSS are quantified and a lake-wide average is determined for that day.

The change in concentration of both Chl and TSS can be determined from comparing an annual average against the baseline. This annual average Chl and TSS will be averaged every 5 years, which will be compared to the Chl and TSS baselines to generate a percentage change. The locations where percentage change is excessive can be targeted for increased water quality monitoring and management.

***Sub-Indicator 3: Quantity (Discharge) of Water in Rivers and Estuaries***

The methodology for this Sub-Indicator describes different techniques for countries to implement to monitor river and estuary discharge. These techniques can include gauging stations or discharge meters. The methodology does not prescribe the type of discharge measurement technique because selection should be based on the size and type of the waterbody, terrain and velocity of water flow, the desired accuracy of measurement, as well as finances available. However, any discharge data collected by countries must adhere to the following minimum criteria:

- Discharge data from each river/estuary monitored should be collected at least once per month. This data should then be averaged to obtain an annual average discharge per river/estuary monitored.
- Each basin should have at minimum of one sampling location, at the point where its water exits into another basin or crosses a national boundary.

Countries will submit 5 years of data on annual average discharges per basin to the custodian agencies. The data from these 5 years will be averaged to smooth short-term variability. To generate national percentage change of discharge over time, a common reference period for all basins must be established. This baseline period will be used to calculate percentage change of discharge for any subsequent 5-year period. To calculate percentage change in discharge for each five year period following the reference period, the following formula is used:

$$\text{Percentage Change in Discharge} = \frac{(\beta - \gamma)}{\beta} \times 100$$

Where β = historical 5 year reference discharge

Where γ = the average discharge of 5 year period of interest

***Sub-Indicator 4: Quality of Water-related Ecosystems***

The methodology for this Sub-Indicator is described in SDG Indicator 6.3.2. The data collected for Indicator 6.3.2 is utilized for Sub-Indicator 4 to inform a calculation of percentage change over time in waterbodies with good ambient water quality.

**Sub-Indicator 5: Quantity of Groundwater within Aquifers**

The methodology for this Sub-Indicator describes a simplified technique for countries to monitor groundwater quantity within aquifers. The volume of groundwater stored in an aquifer is most traditionally estimated using a combination of parameters but for the purposes of Indicator 6.6.1 monitoring, the ‘head’ or level of groundwater within an aquifer can solely be measured as a proxy for groundwater volume within an aquifer. Measuring the level of groundwater within an aquifer is done through the use of boreholes. The methodology does not prescribe the number of boreholes to be monitored per aquifer because the distribution of groundwater can be variable depending on the location and characteristics of aquifers. However, any groundwater level data collected by countries must adhere to the following minimum criteria:

- Point measurements of groundwater level within aquifers should be collected at least twice per year. This data should then be averaged to obtain an annual average groundwater level per aquifer monitored. Understanding the seasonal and other short term changes is a necessary aspect of management of groundwater but should only be considered as part of the local management of the groundwater.
- Each aquifer monitored should have at minimum one borehole that can be used for groundwater level measurements.

Countries will submit 5 years of data on annual average groundwater level per basin to the custodian agencies, which will be averaged to smooth short-term variability. To generate national percentage

change of discharge over time, a common reference period for all basins must be established. This baseline period will be used to calculate percentage change of groundwater quantity for any subsequent 5-year period. To calculate percentage change in quantity for each five year period following the reference period, the following formula is used.

$$\text{Percentage Change in Quantity} = \frac{(\beta - \gamma)}{\beta} \times 100$$

Where β =historical 5 year reference groundwater level

Where γ = the average groundwater level of 5 year period of interest

## 4.f. Treatment of missing values (i) at country level and (ii) at regional level

### Treatment of missing values:

- ***At country level:***

Due to the use of satellite data for some sub-indicators, it is not expected to have missing data for these sub-indicators. For all other sub-indicators, missing values are not imputed.

- ***At regional and global levels:***

Missing values are not imputed.

## 4.g. Regional aggregations

### Regional aggregates:

For the aggregation methods, please see:

http://pre-uneplive.unep.org/media/docs/graphs/aggregation_methods.pdf

## 5. Data availability and disaggregation

# Data availability

### Description:

The data for Sub-Indicators 1 and 2 is available annually. For Sub-Indicators 3, 4, and 5, data is already available from some countries and national authorities should strengthen their monitoring and report efforts to expand data availability for these three sub-indicators.

Data collection for all Sub-Indicators was included in a 2017 data drive to countries; however, the data is still being validated. In addition, national spatial extent data for 188 countries has been collected from 2001-2015 to support Sub-Indicator 1. Data for all 5 Sub-Indicators is reported to UNSD every 5 years.

### Time series:

The reporting on this indicator will follow an annual cycle.

### Disaggregation:

Indicator 6.6.1 can be disaggregated by each Sub-Indicator. All Sub-Indicators can also be disaggregated at different spatial scales i.e.. National, basin, and ecosystem type.

## 6. Comparability/deviation from international standards

### Sources of discrepancies:

NA

## 7. References and Documentation

# References

### URL:

http://www.sdg6monitoring.org/indicators/target-66/indicators661/

# Additional information

The methodology was tested in two pilot phases. The first of these involved designing the methodology in consultation with countries resulting in a first draft of the methodology which was reviewed and strengthened by the Target Team. In early 2016, the draft methodology was pilot tested in five countries between April and November 2016 through workshops: Jordan, the Netherlands, Peru, Senegal, and Uganda. In each of these countries, various participants from national entities and government sectors were engaged to obtain wide feedback on the technical feasibility of the draft methodology.

During the 2016 country pilots of the draft methodology, the NSO from each of the 5 countries was consulted and engaged in the process. During the 2017 pilot methodology data drive, the initial request for data was communicated to all NSOs. In addition, in October 2017 national data on spatial extent of open water (derived from earth observations) was shared with 188 countries, directly via their NSOs (see further details above).